Dedicated to my beloved father

Late Priyanath Brahma

&

My family members

. . . . . .

Barkhang Brahma

DECLARATION

I do hereby declare that the Thesis entitled **"Design and Development of Phase Change Material Integrated Solar Air Heater for Drying Application in Agriculture"** being submitted to the Department of Energy, Tezpur University, is a record of original research work carried out by me. All sources of assistance have been assigned due acknowledgement. I also declare that neither this work as a whole nor a part of it has been submitted to any other University or Institute for any other degree, diploma, or award.

Place: Tezpur **(Barkhang Brahma)**

Date:

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CERTIFICATE OF THE SUPERVISOR

This is to certify that the Thesis entitled **"Design and Development of Phase Change Material Integrated Solar Air Heater for Drying Application in Agriculture"**, submitted to the Department of Energy, School of Engineering, Tezpur University in partial fulfillment for the award of the degree of Doctor of Philosophy in Energy is a record of research work carried out by Mr. Barkhang Brahma under my supervision and guidance.

All help received by him from various sources has been duly acknowledged.

No part of this Thesis has been submitted elsewhere for award of any other degree.

Signature of Supervisor

(Debendra Chandra Baruah)

Designation: Professor

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(Barkhang Brahma)

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LIST OF ABBREVIATION

A	Area of absorber plate
A_d	Drying bed area
AC	Annual cost of PCMSD
AMC	Annual maintenance cost
ASV	Annual salvage value
AUE	Annual useful energy
A_m	Surface area of metal specimens
b	Breadth of the absorber plate
C_d	Cost of drying per kg of dried tomato
c_p	Specific heat of fluid (air)
C_{st}	Specific heat of PCM
CR	Corrosion rate
CRF	Capital recovery factor
CT	Capital cost of PCMSD
d_f	Spacing between glass to absorber plate
d_{PCM}	Depth of the PCM
DSC	Differential scanning calorimetry
D_y	Total number of active sunshine days per annum for PCMSD operation
E_{AO}	Annual thermal energy output of the dryer
E_{DO}	Daily thermal energy output of the PCMSD
$EcPBP$	Economic payback period
$EnPBP$	Energy payback period
E_{emb}	Embodied energy
Ex_{in_c}	Exergy inflow to the collector
Ex_{in_d}	Exergy inflow to the drying chamber
Ex_{loss_c}	Exergy loss of exergy of solar collector
Ex_{loss_d}	Exergy loss of exergy from drying chamber
Ex_{out_c}	Exergy outflow from the collector
Ex_{out_d}	Exergy outflow from the drying chamber
FAC	First annual cost
g	Acceleration due to gravity and gram

Gr	Grashof number
h	Heat transfer coefficient
I	Solar radiation
i	Rate of interest
k	thermal conductivity
L	Length of absorber plate
LHS	Latent heat storage
LHTESS	Latent heat thermal energy storage system
L_1	Length of collector
L_2	Width of collector
L_3	Depth of collector
L_i	Internal losses
L_{st}	Latent heat of PCM
L_t	Transmission losses
L_w	Latent heat of vaporization of water
M	Mass of PCM
$\dot{m}$	Mass flow rate of air
Δm	Mass loss
m_i	Initial mass of tomato
m_f	Final mass of tomato
m_t	Mass of the product (tomato)
$m(t_o)$	Initial mass of the metal specimens
$m(t)$	Final mass of the metal specimens
m_w	Annual moisture removed from tomato
n	Lifetime of PCMSD
N_u	Nusselt number
P_c	Annual power cost
P_{dry}	Price of the dried tomato per kg
$P_{e/kWh}$	Price of the electricity per kWh
P_{fresh}	Price of the fresh tomato per kg
P_r	Prandlt number
PCM	Phase change material
PCMSAH	Phase change material integrated solar sir heater

PCMSD	Phase change material based solar dryer
Q_A	Absorbed heat
Q_{dry}	Quantity of dry tomato produced annually
Q_{fresh}	Quantity of fresh tomato to be dried annually
Q_{loss}	Heat loss
Q_{st}	Heat stored
Q_u	Useful heat
R_a	Roughness average of metal specimens
Ra'	Rayleigh number
R_t	Maximum peak-to-valley height of metal specimens
RPD	Relative percentage difference
S	Savings from PCMSD annually
SAH	Solar air heater
SEC	Specific energy consumption
SFF	Sinking fund factor
SM	Specific moisture extraction
SR	Mass shrinkage ratio
SV	Salvage value
T	Temperature
t	Time of operation per day
T_{ci}	Fluid inlet Temperature
T_m	Mean of inlet and outlet temperature
T_{co}	Fluid outlet temperature
T_r	Sun temperature
TES	Thermal energy storage
TESS	Thermal energy storage system
TGA	Thermogravimetry analysis
U_{loss}	Overall loss-coefficient
V	Velocity
V_o	Outside wind velocity
W	Power consumed by the electric blower
x	Drying bed thickness
Z_p	Absorber plate thickness

α	Absorptivity
α'	Thermal diffusivity
ε	Emissivity
ρ	Density
ρ_t	Bulk density of tomato
τ	Transmissivity
μ	Kinematic viscosity
η	Efficiency
η_{Ex_c}	Exergy efficiency for the solar collector
η_{Ex_d}	Exergy efficiency for the drying chamber
σ	Stefan Boltzmann's constant
θ	Tilt angle
δ_b	Bottom insulation thickness
δ_e	Edge insulation thickness
ζ	Porosity of the drying tray

Subscripts

a	Ambient
av	Average
b	Bottom
c	Channel
con	Convective
d	Drying chamber
e	Edge
f	Fluid (air)
fin_ch	Final charging process
fin_dis	Final discharging process
g	Glass
i	Insulation, inlet
in_ch	Initial charging process
in_dis	Initial discharging process
l	Liquid
p	Absorber plate
rad	Radiative

s	Solid
st	Stored (PCM)
t	Top
w	Wind